PHYSICS

Departmental Office: 704 Pupin; 212-854-3348
http://www.columbia.edu/cu/physics

Director of Undergraduate Studies: Dr. Jeremy Dodd, 924 Pupin; 212-854-3969; jeremy.dodd@columbia.edu

The physics major offers a rigorous preparation in the intellectual developments of modern physics, along with extensive exposure to the mathematical and experimental techniques required to conduct basic and applied research in physics.

For the major, the department offers a set of required courses well-suited to prepare students for the most rigorous course of graduate study. These can be supplemented by elective courses in a variety of advanced topics. Although most majors go on to graduate work in physics, the intellectual skills acquired in the study of physics can also provide the basis for work in a variety of other scientific and nonscientific areas.

The physics concentration is for students who are interested in physics but are uncertain about graduate study in physics; for those who want to explore other subjects along with physics; for those who want to find a physics-related job after graduation; or for those who are considering a professional school such as law or medicine. The department helps concentrators custom design programs to ensure maximum flexibility in meeting students’ intellectual needs and career goals. With appropriate selection of courses, the concentrator can explore other subjects yet maintain the option of graduate study in physics.

Research is an extremely important component of the Columbia physics experience. Because the department has a very small student-to-faculty ratio, essentially all physics majors and concentrators engage in experimental, computational, or theoretical research under the close supervision of a faculty member during part, if not all, of their time at Columbia.

Registration for Introductory Courses

The department offers a stand-alone one-semester course for nonscience majors, one introductory sequence in physics intended primarily for preprofessional students, and three introductory sequences in physics for engineering and physical science majors. Students are given credit for courses from only one of the different sequence groups.

Mixing courses across the sequences is strongly discouraged; however, physics majors who begin their studies with PHYS UN1401 Introduction To Mechanics and Thermodynamics - PHYS UN1402 Introduction To Electricity, Magnetism, and Optics should take PHYS UN2601 Physics, III: Classical and Quantum Waves as the third-semester course.

Introductory Sequences

Nonscience Majors:

PHYS UN1001 Physics for Poets

Preprofessional Students:

PHYS UN1201 General Physics I
- PHYS UN1202 and General Physics II

Accompanying laboratory course:

PHYS UN1291 General Physics Laboratory
- PHYS UN1292 and General Physics Laboratory II

Engineering and Physical Science Majors:

Select one of the following sequences with accompanying laboratory course:

Sequence A:

PHYS UN1401 Introduction To Mechanics and Thermodynamics
- PHYS UN1402 and Introduction To Electricity, Magnetism, and Optics
- PHYS UN1403 and Introduction To Classical and Quantum Waves

Sequence B:

PHYS UN1601 Physics, I: Mechanics and Relativity
- PHYS UN1602 and Physics, II: Thermodynamics,
- PHYS UN2601 and Electricity, and Magnetism
- PHYS UN2801 and Physics, III: Classical and Quantum Waves

Sequence C:

PHYS UN2801 Accelerated Physics I
- PHYS UN2802 and Accelerated Physics II

Sequence A is a self-contained group of three courses, while Sequences B and C anticipate more course work in the Physics Department. Students considering a physics major are strongly encouraged to begin one of these sequences in their first year.

Laboratory

Many of the introductory courses include a laboratory, as indicated. A $75 per term laboratory fee is charged for all 1000-level and 2000-level laboratories.

Advanced Placement

Students may earn a maximum of 6 credits in physics. The department grants 6 credits for a score of 4 or 5 on the AP Physics B exam, but the student is not entitled to any exemptions. The amount of credit is reduced to 3 if the student takes a 1000-level physics course.

The department grants 3 credits for a score of 4 or 5 on the AP Physics C/MECH exam, but the student is not entitled to any exemptions. The amount of credit is reduced to 0 if the student takes PHYS UN1001, PHYS UN1201, PHYS UN1401 or PHYS UN1601.

The department grants 3 credits for a score of 4 or 5 on the AP Physics C/E&ME exam, but the student is not entitled to any exemptions. The amount of credit is reduced to 0 if the student takes PHYS UN1001, PHYS UN1202, PHYS UN1402 or PHYS UN1602.

Professors

Igor Aleiner
Boris Altshuler
Elena Aprile
Dmitri Bassov
Andrei Beloborodov
Allan Blaer (emeritus)
Gustaaf Brooijmans
Norman Christ
Brian Cole
Frederik Denef
Richard Friedberg (Barnard emeritus)
Brian Greene (Mathematics)
Guidelines for all Physics Majors, Concentrators, and Interdepartmental Majors

Majors and concentrators should plan their programs of study with the director of undergraduate studies before the beginning of the junior year. Prospective physics majors are strongly encouraged to begin one of the introductory physics sequences in their first year. Majors should aim to acquire as extensive a background in mathematics as possible.

The department considers laboratory experience to be an essential part of the physics curriculum. Majors and concentrators can gain such experience in the intermediate-level laboratories, the electronics laboratory, and through experimental research in faculty research groups.

Grading
A grade of C- or better must be obtained for a course to count toward the majors or the concentration. The grade of P is not acceptable, but a course that was taken P/D/F may be counted if and only if the P is uncovered by the Registrar’s deadline.

Major in Physics

Physics Courses
The major in physics requires a minimum of 41 points in physics courses, including:

Introductory Sequences
Select one of the following sequences:

Sequence A: Students with a limited background in high school physics may elect to take:

PHYS UN1401
- PHYS UN1402
- PHYS UN2601
Introduction To Mechanics and Thermodynamics
and Introduction To Electricity, Magnetism, and Optics
and Physics, III: Classical and Quantum Waves

Sequence B:

PHYS UN1601
- PHYS UN1602
- PHYS UN2601
Physics, I: Mechanics and Relativity
and Physics, II: Thermodynamics,
Electricity, and Magnetism
and Physics, III: Classical and Quantum Waves

Sequence C: Students with advanced preparation in both physics and mathematics may be eligible to take:

PHYS UN2801
- PHYS UN2802
Accelerated Physics I
and Accelerated Physics II

Core Physics Courses

PHYS UN3003
Mechanics

PHYS UN3007
Electricity and Magnetism

PHYS UN3008
Electromagnetic Waves and Optics

PHYS GU4021
Quantum Mechanics I

PHYS GU4022
Quantum Mechanics II

PHYS GU4023
Thermal and Statistical Physics

Elective Courses
Select at least six points of the following courses:

PHYS UN3002
From Quarks To the Cosmos:
Applications of Modern Physics

PHYS GU4003
Advanced Mechanics

Associate Professors
Brian Humensky
Janna Levin (Barnard)
Brian Metzger
Alberto Nicolis
Abhay Pasupathy
Ozgur Sahin (Biology)
Tanya Zelevinsky

Assistant Professors
Cory Dean
Bradley Johnson
Georgia Karagiorgi
Rachel Rosen
Sebastian Will

Senior Lecturer in Discipline
Jeremy Dodd

Adjunct Professor
Morgan May

Lecturer
Burton Budick
Eric Raymer

On Leave
Amber Miller
For chemical physics requirements please see:
http://bulletin.columbia.edu/columbia-college/departments-instruction/chemistry/#requirementstext

For biophysics requirements please see:
http://bulletin.columbia.edu/columbia-college/departments-instruction/biological-sciences/#requirementstext

For astrophysics requirements please see:
(astronomy, biological sciences, chemistry).

It is also possible to major in astrophysics, biophysics, and chemical physics. Students interested in these areas should consult with the director of undergraduate studies and with cognate departments (astronomy, biological sciences, chemistry).

For astrophysics requirements please see:

For biophysics requirements please see:

For chemical physics requirements please see:
http://bulletin.columbia.edu/columbia-college/departments-instruction/chemistry/#requirementstext

**Mathematics Courses**

Calculus through MATH UN1202 Calculus IV or MATH UN1208 Honors Mathematics B; and MATH UN3027 Ordinary Differential Equations or the equivalent.

Recommended cognate courses: MATH UN2010 Linear Algebra, MATH UN3007 Complex Variables, and MATH UN3028 Partial Differential Equations.

**Concentration in Physics**

The concentration in physics requires a minimum of 24 points in physics, including one of the introductory sequences.

**Interdisciplinary Major**

It is also possible to major in astrophysics, biophysics, and chemical physics. Students interested in these areas should consult with the director of undergraduate studies and with cognate departments (astronomy, biological sciences, chemistry).

For astrophysics requirements please see:
http://bulletin.columbia.edu/columbia-college/departments-instruction/astronomy/#requirementstext

For biophysics requirements please see:
http://bulletin.columbia.edu/columbia-college/departments-instruction/biological-sciences/#requirementstext

For chemical physics requirements please see:
http://bulletin.columbia.edu/columbia-college/departments-instruction/chemistry/#requirementstext

**Physics UN1001 Physics for Poets. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: high school algebra.

This course does not fulfill the physics requirement for admission to medical school. No previous background in physics is expected. An introduction to physics taught through the exploration of the scientific method, and the application of physical principles to a wide range of topics from quantum mechanics to cosmology.

**Physics UN1018 Weapons of Mass Destruction. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: high school science and math.

A review of the history and environmental consequences of nuclear, chemical, and biological weapons of mass destruction (WMD); of how these weapons work, what they cost, how they have spread, how they might be used, how they are currently controlled by international treaties and domestic legislation, and what issues of policy and technology arise in current debates on WMD. What aspects of the manufacture of WMD are easily addressed, and what aspects are technically challenging? It may be expected that current events/headlines will be discussed in class.

**Physics UN1111 Origins and Meaning. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

This seminar is a one-semester survey of the universe from the beginning of time to something akin to its end, with an organizing theme of origins. We will explore the origin of inanimate physical structures (the origin of cosmos as a whole, as well as that of galaxies, stars, planets, particles, atoms and complex molecules), the origin of life (the origin of replicating molecules, the first cells, as well as more complex life forms), the origin of mind (the origin of self-reflective conscious awareness) and the origin of culture (the origins of language, myth, religion, art and science). We will consider the adaptive role of these developments and then consider what science in particular tells us about the far future of matter and mind. Throughout, we will examine the long-standing human search for meaning.

**Physics UN1201 General Physics I. 3 points.**

CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: some basic background in calculus or be concurrently taking MATH UN1101 Calculus I.. The accompanying laboratory is PHYS UN1291-UN1292

The course will use elementary concepts from calculus. The accompanying laboratory is PHYS UN1291 - UN1292. Basic introduction to the study of mechanics, fluids, thermodynamics, electricity, magnetism, optics, special relativity, quantum mechanics, atomic physics, and nuclear physics.

**Spring 2020: PHYS UN1201**

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<th>Points</th>
<th>Enrollment</th>
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<td>001/15688</td>
<td>M W 5:40pm - 6:55pm</td>
<td>P. Michael Tuts</td>
<td>3</td>
<td>70/130</td>
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</table>
PHYS UN1202 General Physics II. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: This course will use elementary concepts from calculus. Students should therefore have had some high school calculus, or be concurrently enrolled in MATH UN1101. Taken with accompanying lab PHYS UN1291- PHYS UN1292, the sequence PHYS UN1201- PHYS UN1202 satisfies requirements for medical school. Electricity, magnetism, optics, and modern physics.

Corequisites: PHYS UN1201, PHYS UN1202

This course is the laboratory for the corequisite lecture course and can be taken only during the same term as the corresponding lecture.

PHYS UN1291 General Physics Laboratory. 1 point.
Same course as PHYS W1291x, but given off-sequence.

Corequisites: PHYS UN1201
This course is the laboratory for the corequisite lecture course and can be taken only during the same term as the corresponding lecture.

PHYS UN1292 General Physics Laboratory II. 1 point.
Corequisites: PHYS UN1201, PHYS UN1202
This course is the laboratory for the corequisite lecture course (PHYS UN1201 - PHYS UN1202) and can be taken only during the same term as the corresponding lecture.

PHYS UN1401 Introduction To Mechanics and Thermodynamics. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Corequisites: MATH UN1101
Fundamental laws of mechanics, kinematics and dynamics, work and energy, rotational dynamics, oscillations, gravitation, fluids, temperature and heat, gas laws, the first and second laws of thermodynamics.
Corequisite: MATH UN1101 or the equivalent.
PHYS UN1402 Introduction To Electricity, Magnetism, and Optics. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: PHYS UN1401
Corequisites: MATH UN1102
Electric fields, direct currents, magnetic fields, alternating currents, electromagnetic waves, polarization, geometrical optics, interference, and diffraction. Corequisite: MATH UN1102 Calculus II or equivalent.

Spring 2020: PHYS UN1402

<table>
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<th>Course Number</th>
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<tr>
<td>PHYS 1402</td>
<td>001/15891</td>
<td>M W 1:10pm - 2:25pm 301 Pupin Laboratories</td>
<td>Georgia Karagiorgi</td>
<td>3</td>
<td>145/160</td>
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<tr>
<td>PHYS 1402</td>
<td>002/15893</td>
<td>T Th 10:10am - 11:25am 301 Pupin Laboratories</td>
<td>Tanya Zelevinsky</td>
<td>3</td>
<td>158/160</td>
</tr>
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PHYS UN1403 Introduction to Classical and Quantum Waves. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: PHYS UN1402 PHYS W1402.
Corequisites: MATH V1201 or the equivalent.
Classical waves and the wave equation, Fourier series and integrals, normal modes, wave-particle duality, the uncertainty principle, basic principles of quantum mechanics, energy levels, reflection and transmission coefficients, applications to atomic physics.

PHYS UN1493 Introduction to Experimental Physics. 3 points.
Prerequisites: PHYS UN1401 and PHYS UN1402
Laboratory work associated with the two prerequisite lecture courses. Experiments in mechanics, thermodynamics, electricity, magnetism, optics, wave motion, atomic physics, and nuclear physics. Note: Students cannot receive credit for both PHYS UN1493 and UN1494.

Spring 2020: PHYS UN1494

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<tr>
<th>Course Number</th>
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<td>003/15971</td>
<td>W 1:00pm - 4:00pm 5th Flr Pupin Laboratories</td>
<td>Guanhao Sun</td>
<td>3</td>
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<td>PHYS 1494</td>
<td>004/15972</td>
<td>T 3:00pm - 3:55pm 428 Pupin Laboratories</td>
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<td>3</td>
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<td>PHYS 1494</td>
<td>005/15973</td>
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<td>Guanhao Sun</td>
<td>3</td>
<td>16/15</td>
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<tr>
<td>PHYS 1494</td>
<td>006/15974</td>
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<td>16/15</td>
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<tr>
<td>PHYS 1494</td>
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<td>PHYS 1494</td>
<td>008/15976</td>
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<td>13/15</td>
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<tr>
<td>PHYS 1494</td>
<td>009/15977</td>
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<td>Guanhao Sun</td>
<td>3</td>
<td>13/15</td>
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PHYS UN1601 Physics, I: Mechanics and Relativity. 3.5 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: Corequisite: MATH UN1102 Calculus II or equivalent. Fundamental laws of mechanics, kinematics and dynamics, work and energy, rotational dynamics, oscillations, gravitation, fluids, introduction to special relativity and relativistic kinematics. The course is preparatory for advanced work in physics and related fields.

PHYS UN1602 Physics, II: Thermodynamics, Electricity, and Magnetism. 3.5 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: PHYS UN1601 Corequisite: MATH UN1201 or equivalent. Temperature and heat, gas laws, the first and second laws of thermodynamics, kinetic theory of gases, electric fields, direct currents, magnetic fields, alternating currents, electromagnetic waves. The course is preparatory for advanced work in physics and related fields.

Spring 2020: PHYS UN1602

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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
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<th>Enrollment</th>
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<tr>
<td>PHYS 1602</td>
<td>001/15894</td>
<td>T Th 10:10am - 11:25am 428 Pupin Laboratories</td>
<td>Jeremy Dodd</td>
<td>3.5</td>
<td>117/180</td>
</tr>
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</table>
PHYS UN2001 Special Relativity. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: a working knowledge of high school algebra, trigonometry, and physics. Some familiarity with calculus is useful but not essential. This course is a comprehensive, one-semester introduction to the essential ideas and mathematical structures underlying Einstein’s Special Theory of Relativity. Among the topics covered will be: the relativity of simultaneity, time dilation, Lorentz contraction, velocity combination laws, time dilation over large distances, the Lorentz transformation, spacetime diagrams, the basic (seeming) paradoxes of special relativity, relativistic equations of motion and E = mc^2.

PHYS UN2601 Physics, III: Classical and Quantum Waves. 3.5 points.
Prerequisites: PHYS UN1402 or PHYS UN1602 Corequisite: MATH UN1202 or equivalent.
Classical waves and the wave equation, geometrical optics, interference and diffraction, Fourier series and integrals, normal modes, wave-particle duality, the uncertainty principle, basic principles of quantum mechanics, energy levels, reflection and transmission coefficients, the harmonic oscillator. The course is preparatory for advanced work in physics and related fields.

PHYS UN2699 Experiments in Classical and Modern Physics. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: (PHYS UN1601 or PHYS UN1401) and (PHYS UN1602 or PHYS UN1402) and PHYS UN2601 PHYS W1601 (or W1401), W1602 (or W1402), and W2601.
Laboratory work associated with the three prerequisite lecture courses. Experiments in mechanics, thermodynamics, electricity, magnetism, optics, wave motion, atomic physics, and nuclear physics.

PHYS UN2801 Accelerated Physics I. 4.5 points.
Prerequisites: Advanced Placement in physics and mathematics, or the equivalent, and the instructor’s permission. (A special placement meeting is held during Orientation.)
This accelerated two-semester sequence covers the subject matter of PHYS UN1601, PHYS UN1602 and PHYS UN2601, and is intended for those students who have an exceptionally strong background in both physics and mathematics. The course is preparatory for advanced work in physics and related fields. There is no accompanying laboratory; however, students are encouraged to take the intermediate laboratory, PHYS UN3081, in the following year.

PHYS UN2802 Accelerated Physics II. 4.5 points.
Prerequisites: PHYS UN2801
This accelerated two-semester sequence covers the subject matter of PHYS UN1601, PHYS UN1602 and PHYS UN2601, and is intended for those students who have an exceptionally strong background in both physics and mathematics. The course is preparatory for advanced work in physics and related fields. There is no accompanying laboratory; however, students are encouraged to take the intermediate laboratory, PHYS UN3081, in the following year.

PHYS UN2804 Disc Section Accelerated Physics II. 0 points.
Required discussion section for PHYS UN2802 Accelerated Physics II.

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<th>Course</th>
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<tr>
<td>PHYS 2804</td>
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<td>W 5:10pm - 6:00pm</td>
<td>Brian Cole</td>
<td>0</td>
<td>18/30</td>
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<tr>
<td>PHYS 2804</td>
<td>002/16367</td>
<td>Th 7:10pm - 8:00pm</td>
<td>Brian Cole</td>
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PHYS UN3002 From Quarks To the Cosmos: Applications of Modern Physics. 3.5 points.
Not offered during 2019-20 academic year.

Prerequisites: PHYS UN2601 or PHYS UN2802
This course reinforces basic ideas of modern physics through applications to nuclear physics, high energy physics, astrophysics and cosmology. The ongoing Columbia research programs in these fields are used as practical examples. The course is preparatory for advanced work in physics and related fields.

PHYS UN3003 Mechanics. 3 points.
Prerequisites: general physics, and differential and integral calculus. Newtonian mechanics, oscillations and resonance, conservative forces and potential energy, central forces, non-inertial frames of reference, rigid body motion, an introduction to Lagrange’s formulation of mechanics, coupled oscillators, and normal modes.

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<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
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<tr>
<td>PHYS 3003</td>
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<td>M W 10:00am - 11:25am</td>
<td>John Parsons</td>
<td>3</td>
<td>37/70</td>
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</table>

PHYS UN3007 Electricity and Magnetism. 3 points.
Prerequisites: general physics, and differential and integral calculus. Electrostatics and magnetostatics, Laplace’s equation and boundary-value problems, multipole expansions, dielectric and magnetic materials, Faraday’s law, AC circuits, Maxwell’s equations, Lorentz covariance, and special relativity.

PHYS UN3008 Electromagnetic Waves and Optics. 3 points.
Prerequisites: PHYS UN3008
Maxwell’s equations and electromagnetic potentials, the wave equation, propagation of plane waves, reflection and refraction, geometrical optics, transmission lines, wave guides, resonant cavities, radiation, interference of waves, and diffraction.

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<th>Section/Call Number</th>
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<tr>
<td>PHYS 3008</td>
<td>001/15898</td>
<td>M W 11:40am - 12:55pm</td>
<td>Alfred Mueller</td>
<td>3</td>
<td>36/70</td>
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</table>
PHYS UN3072 Seminar in Current Research Problems. **2 points.**
May be taken for Pass/Fail credit only.

A detailed study of a selected field of active research in physics. The motivation, techniques, and results obtained to the present, as well as the difficulties and unsolved problems. For Physics majors only. Priority given to seniors; juniors by permission of the instructor.

Spring 2020: PHYS UN3072

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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<td>PHYS 3072</td>
<td>001/15899</td>
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<td>Yasutomo</td>
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<td>25/40</td>
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<td></td>
<td></td>
<td>705 Pupin Laboratories</td>
<td>Uemura</td>
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</table>

PHYS UN3081 Intermediate Laboratory Work. **2 points.**
May be repeated for credit by performing different experiments. The laboratory has available fifteen individual experiments, of which two are required per 2 points.

Prerequisites: phys UN2601 or phys un2802 Primarily for junior and senior physics majors; other majors must obtain the instructor’s permission.

Each experiment is chosen by the student in consultation with the instructor. Each section meets one afternoon per week, with registration in each section limited by the laboratory capacity. Experiments (classical and modern) cover topics in electricity, magnetism, optics, atomic physics, and nuclear physics.

Spring 2020: PHYS UN3081

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<th>Course Number</th>
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<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>PHYS 3081</td>
<td>002/15901</td>
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<td>Sebastian</td>
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<td>10/10</td>
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<tr>
<td></td>
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<td>6th Flr Pupin Laboratories</td>
<td>Will</td>
<td></td>
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<td>PHYS 3081</td>
<td>003/15902</td>
<td>F 1:10pm - 5:00pm</td>
<td>Morgan</td>
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<td>May</td>
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PHYS UN3083 Electronics Laboratory. **3 points.**
Enrollment limited to the capacity of the laboratory.

Prerequisites: PHYS UN3003 or PHYS UN3007 May be taken before or concurrently with this course.

A sequence of experiments in solid-state electronics, with introductory lectures.

Spring 2020: PHYS UN3083

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<th>Course Number</th>
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<td>001/15903</td>
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<td>John</td>
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PHYS UN3500 Supervised Readings in Physics. **3 points.**
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: the written permission of the faculty member who agrees to act as supervisor, and the director of undergraduate studies’ permission.

Readings in a selected field of physics under the supervision of a faculty member. Written reports and periodic conferences with the instructor.

Spring 2020: PHYS UN3500

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<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<td>PHYS 3500</td>
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PHYS UN3900 Supervised Individual Research. **1-5 points.**
Prerequisites: the written permission of the faculty member who agrees to act as supervisor, and the director of undergraduate studies’ permission.

For specially selected physics majors, the opportunity to do a research project in contemporary physics under the supervision of a faculty member. A detailed report on the research is presented by the student when the project is completed.

Spring 2020: PHYS UN3900

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PHYS GU4003 Advanced Mechanics. **3 points.**
Prerequisites: differential and integral calculus, differential equations, and PHYS UN3003 or the equivalent.

Lagrange’s formulation of mechanics, calculus of variations and the Action Principle, Hamilton’s formulation of mechanics, rigid body motion, Euler angles, continuum mechanics, introduction to chaotic dynamics.

Spring 2020: PHYS GU4003

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PHYS GU4011 Particle Astrophysics and Cosmology. **3 points.**
Prerequisites: (PHYS UN1403 or PHYS UN2601 or PHYS UN2802) and (MATH UN1202 or MATH UN1208) students are recommended but not required to have taken PHYS UN3003 and PHYS UN3007.

An introduction to the basics of particle astrophysics and cosmology. Particle physics - introduction to the Standard Model and supersymmetry/higher dimension theories; Cosmology – Friedmann-Robertson-Walker line element and equation for expansion of universe; time evolution of energy/matter density from the Big Bang; inflationary cosmology; microwave background theory and observation; structure formation; dark energy; observational tests of geometry of universe and expansion; observational evidence for dark matter; motivation for existence of dark matter from particle physics; experimental searches of dark matter; evaporating and primordial black holes; ultra-high energy phenomena (gamma-rays and cosmic-rays).

Spring 2020: PHYS GU4011

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PHYS GU4012 String Theory. **3 points.**
Prerequisites: PHYS UN3003 and PHYS UN3008 and PHYS GU4021.

PHYS GU4023 would be helpful but is not required. Students should have some familiarity with tools for graphical presentation and numeric problem solving such as Mathematica and/or MatLab.

This course is intended as an introduction to string theory for undergraduates. No advanced graduate-level preparation is assumed, and the material will be covered at (no higher than) the advanced undergraduate level. Advanced topics such as supersymmetry, T-duality, and covariant quantization will not be covered. The focus will be on the dynamics of classical and quantum mechanical strings, with an emphasis on integrating undergraduate material in classical mechanics, relativity, electrodynamics and quantum mechanics.
PHYS GU4018 Solid-State Physics. 3 points.
Prerequisites: PHYS GU4021 and PHYS GU4023 or the equivalent.
Introduction to solid-state physics: crystal structures, properties of periodic lattices, electrons in metals, band structure, transport properties, semiconductors, magnetism, and superconductivity.

PHYS GU4019 Mathematical Methods of Physics. 3 points.
Prerequisites: PHYS UN3003 and PHYS UN3007 and differential and integral calculus; linear algebra; or the instructor’s permission. This course will present a wide variety of mathematical ideas and techniques used in the study of physical systems. Topics will include: ordinary and partial differential equations; generalized functions; integral transforms; Green’s functions; nonlinear equations, chaos, and solitons; Hilbert space and linear operators; Feynman path integrals; Riemannian manifolds; tensor analysis; probability and statistics. There will also be a discussion of applications to classical mechanics, fluid dynamics, electromagnetism, plasma physics, quantum mechanics, and general relativity.

PHYS GU4021 Quantum Mechanics I. 3 points.
Prerequisites: PHYS UN3003 and PHYS UN3007

PHYS GU4022 Quantum Mechanics II. 3 points.
Prerequisites: PHYS GU4021. Formulation of quantum mechanics in terms of state vectors and linear operators, three-dimensional spherically symmetric potentials, the theory of angular momentum and spin, time-independent and time-dependent perturbation theory, scattering theory, and identical particles. Selected phenomena from atomic physics, nuclear physics, and elementary particle physics are described and then interpreted using quantum mechanical models.

PHYS GU4023 Thermal and Statistical Physics. 3 points.
Prerequisites: PHYS GU4021 or the equivalent.
Thermodynamics, kinetic theory, and methods of statistical mechanics; energy and entropy; Boltzmann, Fermi, and Bose distributions; ideal and real gases; blackbody radiation; chemical equilibrium; phase transitions; ferromagnetism.

PHYS GU4024 Applied Quantum Mechanics. 3 points.
Prerequisites: (PHYS GU4021 and PHYS GU4022)
In this course, we will learn how the concepts of quantum mechanics are applied to real physical systems, and how they enable novel applications in quantum optics and quantum information. We will start with microscopic, elementary quantum systems – electrons, atoms, and ions - and understand how light interacts with atoms. Equipped with these foundations, we will discuss fundamental quantum applications, such as atomic clocks, laser cooling and ultracold quantum gases - a synthetic form of matter, cooled down to just a silver above absolute zero temperature. This leads us to manybody quantum systems. We will introduce the quantum physics of insulating and metallic behavior, superfluidity and quantum magnetism – and demonstrate how the corresponding concepts apply both to real condensed matter systems and ultracold quantum gases. The course will conclude with a discussion of the basics of quantum information science - bringing us to the forefront of today’s quantum applications.

PHYS GU4040 Introduction to General Relativity. 3 points.
Prerequisites: PHYS UN3003 and PHYS UN3007 or the equivalent. Tensor algebra, tensor analysis, introduction to Riemann geometry. Motion of particles, fluid, and fields in curved spacetime. Einstein equation. Schwarzschild solution; test-particle orbits and light bending. Introduction to black holes, gravitational waves, and cosmological models.

PHYS GU4050 Introduction to Particle Physics. 3 points.
Prerequisites: PHYS UN2601 or PHYS UN2802 or the equivalent. This course covers the Standard Model of Particle Physics, including its conception, successes, and limitations, with the goal of introducing upper-level physics majors to the foundations and current status of particle physics as a field of research. Specific topics to be covered include: historical introduction and review of the Standard Model; particle interactions and particle dynamics; relativistic kinematics; Feynman calculus, quantum electrodynamics, quantum chromodynamics, and weak interactions; electroweak unification and the Higgs mechanism; neutrino oscillations; and beyond-standard model physics and evidence. Along the way, students will research special topics and familiarize themselves with particle physics research.